Engineering Case Library

ECL 94

Development of a New Drill Steel

at

Ingersoll-Rand Company

Rock drills are used in mining, in excavating, and in other applications where it is necessary to remove hard rock. The drills produce holes into which blasting charges are later inserted. These holes may be as shallow as a few feet or as deep as one hundred feet. Depths of fifty feet are common. The holes are produced by a bit which is attached to one end of the drill rod (or "steel"). A pneumatic hammer hits the other end of the drill steel, through a so-called "shank piece". The drill steels themselves, each about ten feet long and one and a half inches in diameter, are threaded at both ends and joined by couplings (see Figure 1).

The total consumption of drill steel has been estimated at between ten and twenty million dollars per year for the entire world, or between 200,000 and 400,000 rods. Ingersoll-Rand is a major producer with a substantial share of this market. In the early 1960's salesmen and distributors began to report that sales were being lost to the competition; the frequency with which this was occurring and the comments of the dealers indicated that Ingersoll-Rand was in danger of losing its position in the field. It was the responsibility of Bob Thompson to look for innovations by which the division might make a profit. Thompson was Development Engineer for the Rock Drill Sales Department. He had been with Ingersoll-Rand since completing service in 1954 and was a 1951 graduate of the Missouri School of Mines in Rolla. He was convinced that it was necessary for continued profit and for maintaining a position of leadership to improve the performance of the drill steels. Consequently, Thompson helped to initiate a number of "Development Expenditure Requisitions" of which an example (not related) is shown in Appendix I.

The task of designing an improved drill steel fell primarily to J. D. Ditson, a veteran who had been with the company for twenty-five years, starting in the Engineering Department and progressing from there to Metallurgy, to Manufacturing Engineering, and finally to Product Engineering. Ditson managed the bit and steel Product Engineering Group under Ewald Kurt, Engineer in Charge of the Rock Drill Division.

Prepared in the Design Division of the Department of Mechanical Engineering by Professor H. O. Fuchs and Ronald J. Shuman with financial support from the National Science Foundation.

In 1964, Ingersoll-Rand was producing two types of drill steel, one commonly called "reconditionable" becuase it could be provided with a new thread after the old one had worn or broken as a result of the continual violent hammer blows. This type is shown in Figure 2a. The other type was called "carburized" because the surface of the drill steel had a higher carbon content than the interior. The surface of the carburized rod is heat treated to make it file hard. This has two advantages: the increased hardness reduces wear, and during the hardening process the steel closest to the surface tries to expand by a small amount. The expansion is prevented by the interior material, and as a result compressive self-stresses are produced in the outermost layer of the steel. These stresses tend to prevent or delay failure. A sketch of the carburized rod is shown in Figure 2b. The sketches show that both rods use shallow threads. The shallow thread is more resistant to fatigue than a thread with sharper grooves would be, and it also provides more friction for locking the rods to the bits and shanks, or in the case of extension rods to the coupling which joins two rods together. Both types of rods have holes through the center which conduct air and water to the bit cutting face for expelling chips and for reducing the dust hazard. The two types of rod must be shaped differently because the file hard surface of the carburized rod cannot be held or turned by the same type of wrench that is used with the reconditionable rod.

Under typical conditions the reconditionable rod can be used to drill about 2,000 feet of hole in hard rock before it is necessary to cut a new thread. Such a rod costs about fifty dollars. The carburized rod lasts for 4,000 feet of hole under the same conditions. It costs about sixty dollars. When it breaks it cannot be reconditioned.

Performance of competitive drill steels was established from field reports made by salesmen and service representatives in the course of the routine performance of their jobs as well as from block testing of rods in Ingersoll-Rand's Phillipsburg plant. Block testing was done by actually running a drill steel, drilling holes in granite blocks at a test facility maintained especially for that purpose at Phillipsburg.

Performance of competitive rods exceeded that of the Ingersoll-Rand reconditionable steel. The competitive rods were reconditionable and subsequent usage, while not as great per rethreading as the original, did extend rod life considerably. Total performance life of these rods, while not equal to that of the Ingersoll-Rand carburized rod, was close enough to make it competitive.

Several attempts were made to improve the performance of the rod without materially affecting the cost. Field reports showed that a harder thread surface was required to provide more abrasion resistance. This could be accomplished by subjecting the threaded rod end to an additional heat treating process. When this was done thread life was extended but rod life was shortened. Fatigue failure occurred after short periods of operation, and it was localized just where the zone of higher hardness ended. Analysis revealed that the degree of hardness at the break was even less than that of the original rod end. At the end of the zone of higher hardness there is a region where the heat used in the second hardening process is sufficient to reduce the previously existing hardness, but not high enough to transform the steel into the condition from which it must be quenched to obtain increased hardness; this zone becomes softer than the rest of the rod and is, therefore, more vulnerable to fatigue failure.

To overcome this defect Ditson devised a new method for hardening the threaded ends (refer to Patent #3,144,365 shown in Appendix II). Steels made by this process performed as well as competitive rods and better than Ingersoll-Rand's reconditionable steels of the production type. But Ditson was not satisfied with the improvement. If, he reasoned, one could combine the durability of the carburized rod with a practical method of reconditioning worn or broken rods, the result would be a clearly superior product.

He kept thinking about this problem day after day, discussing it with several of his associates in Product Engineering and with Bob Thompson. Eventually, he conceived the idea of threading a drill steel from end to end. The continuous thread would have two advantages: it would avoid the stress concentration which occurs at any change of section, and it would permit the user to recondition a carburized rod by simply grinding off a broken end and attaching the coupling or bit to the fresh thread which was exposed. There was one obvious difficulty: some means would be needed to loosen the rod from the coupling or bit in which it was engaged. The function of the hexagon shank of the old carburized drill steel in providing wrench flats was difficult to duplicate. Attention focused on finding a means of disengaging a drill steel without the use of a wrench. In modern rock drilling equipment the rotation and hammering functions can be controlled independently, and Ditson recalled a technique he had seen used "informally" in the field: by stopping the rotation and continuing to hammer on the upper end of the drill steel it was possible to loosen the coupling parts. Under these conditions the drill steel would begin to disengage itself and could then be unscrewed by hand. Ditson experimented with this technique and discovered that it was equal effective with the threaded rods. Thus, the idea of continuous threading seeme feasible, provided an economical way could be found of producing a ten foot lon thread in the alloy steel. He requested quotations from various commercial thread rolling operators and started inquiries with the manufacturers of thread rolling machines. Eventually, it became clear that if Ingersoll-Rand wanted to go into production with the new drill rod they would have to buy the thread rolling machines required to produce the threads. Such a machine would cost around $75,000. John Adams (Columbia 1958), Manager of Development for the Rock Drill Division, faced the problem of justifying this expenditure to the Ingersoll-Rand management.

He knew already that drill steels made by this new method would last far longer before breaking than any known before, and that, in addition, they could be used again after they broke; the company had spent several thousand dollars to establish this fact. They had purchased a special set of thread rolling dies and had ground twenty 1 1/2 inch diameter bars of alloy steel down to the diameter of 1.438 inches which, after rolling, would produce the desired thread size. The twenty rods had been rolled by the Landis Company, which manufactures thread rolling machines, and had been heat treated by the same supplier who had carburized the production rods. Ten of these experimental drill steels had been sent to the operator of a quarry near Phillipsburg to see if any snags would develop in field service. The results had been excellent.

It seemed reasonable to assume that with such excellent drill steels Ingersoll-Rand would capture a larger percentage of the total market than they had before. The question was how much larger. If Adams estimated the percentage too low his calculation would show that it would take several years for the new machine to pay for itself and there was a chance that the company would decide not to buy such a machine, since it could not be justified except to produce these special drill steels. If, on the other hand, he estimated the percentage too high, then the company might proceed from his estimate, price the new drill steels accordingly, and perhaps lose money on them. Adams tried to imagine himself in the role of a consumer in order to arrive at a reasonable estimate of the new product's value. Finally, he concluded that customers would buy at least fifty per cent more of the new drill steel from Ingersoll-Rand than of the previous two types. He submitted this estimate to Tom Holmes, the General Manager of the Rock Drill Division, who had followed the development of the new steel and was enthusiastic about its potential. Holmes decided to increase the estimate and pass it on to the Group Vice President, Bill Wearly, who also increased it before passing it on to the Capital Investment Committee which approved it.

The machine was purchased and a first production lot was started. The first batch of new drill steels was carefully checked for dimensional accuracy, chemical composition, surface hardness, core hardness, and finish. Inspection revealed unexpected surface flaking of the thread and bad overall appearance; the product was obviously unsatisfactory for field introduction. The severity of effect of these flaws on performance was unknown, but the rods were definitely not comparable with the experimental ones. Several of the defective steels were sent to the supplier of the thread rolling equipment for analysis, and additional samples were given close scrutiny in the Metallurgical Department at Phillipsburg. Both sources reported that the flaking initiated at small seams on the outside surface of the blank which had not been removed in the sizing operation.

Representatives of the steel supplier were called in to determine the cause of these defects and methods to avoid them. They found that one reason for the excellent performance of the experimental steels was the large amount of metal which had to be removed from the surface in order to produce the correct diameter for thread rolling. In ordering tonnage quantities, neither Ingersoll-Rand nor the steel mill had recognized the importance of removing the normal shallow surface seam that occurs in this type of product. The problem was solved in succeeding lots by specifying that the steel be rolled to a slightly larger diameter to leave more finish allowance. Appendix III illustrates some details of the continuously threaded rod in its production form.

A year after Adams' initial prediction the sales returns began to show that it had been quite conservative. Even his boss's increased estimates had been exceeded. The following letter from the cognizant Product Engineer in the Rock Drill Sales Department to all dealers is a good indication of the success of this product.

IR Ingersoll-Rand

subject Spiral Steel
date April 26, 1967

Dear Sir:

We have just received an interesting report from Craig Walters, our salesman in the Baltimore territory, concerning the sales of Spiral Steel to the Nello Teer Company.

This report covered a cost comparison between the steel made by a competitor and our Spiral Steel, and we will report the results as Craig gave them to us.

The competitive steels were sold for a cost of $34.00 for a 10 ft. length and the thread life on each use was 800 ft. The steels were reworked 4 times at a cost of $6.00 per end and the total life of the steel, before discard, was 3200 ft. They were using one coupling for each set of threads at a price of $7.00 each.

The Spiral Steel was sold at U.S. List with the thread life of 6000 ft. at each use and the steels were reworked 4 times with a total rod life of 24,000 ft. They used 2 1/2 couplings per set of threads and couplings were sold at $9.65 each.

Summarizing, the total cost per foot for the competitive steel was 3 1/2 cents and the total cost per foot for the Spiral Steel was 3/4 cents per foot.

Craig sums up his report by stating that on the basis of the above information, Ingersoll-Rand Company has a standing order for drill steel from the Nello Teer Company.

On this job, they have six (6) drills and each drill drills 380 ft. per 8-hour shift. The total footage per day is 2280 and the total footage per year is 550,000 ft. The customer changed over to our steel when he realized that he could save a possible $15,000.00 per year in drill steel by using the Spiral Steel.

This is typical of the stories we have on this product.

You should talk to your dealers, solicit stock orders, and convince your dealer salesmen to sell this product with confidence.

Very truly yours,

INGERSOLL-RAND COMPANY

/s/

Product Engineer
Rock Drill Sales Department

TO: All Rock Drill Price Book Holders - Ingersoll-Rand Domestic, Export, and Export Dealers on Rock Drill Price Book Mailing List.

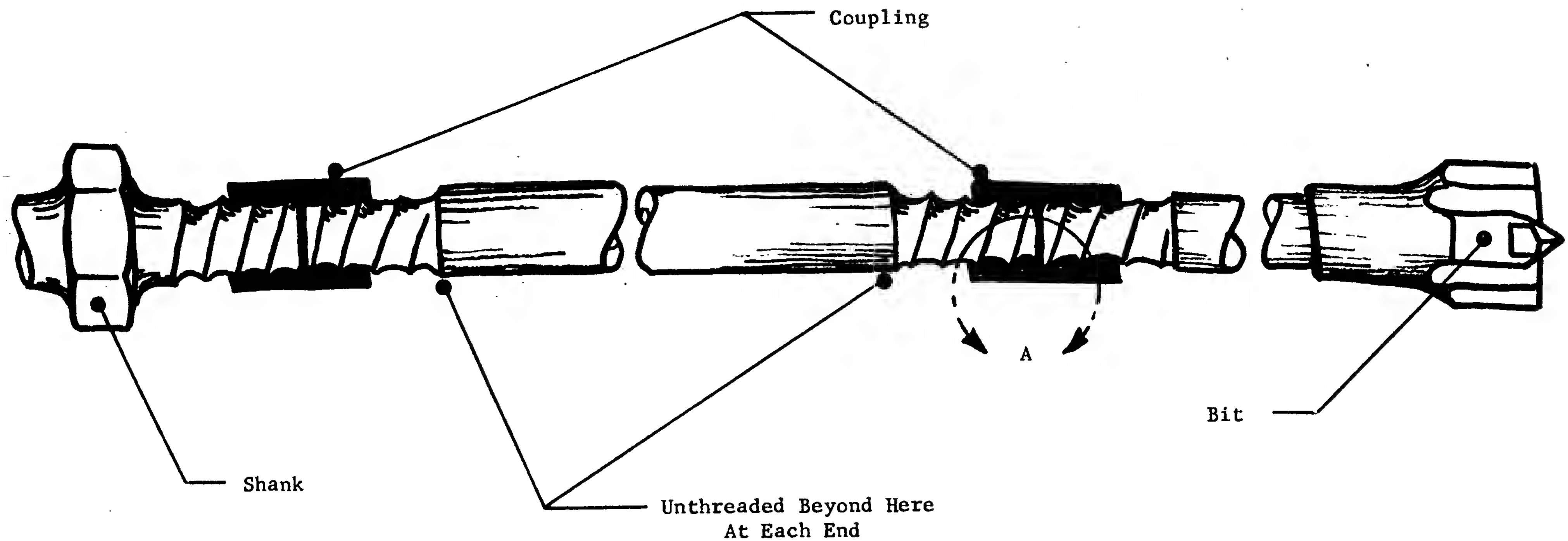
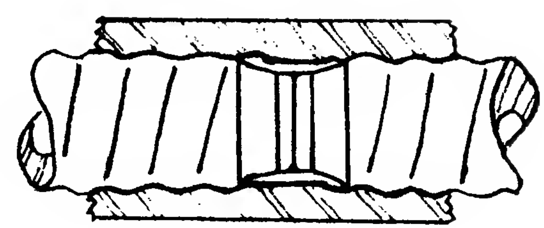


Figure 1



Detail A

Figure 2

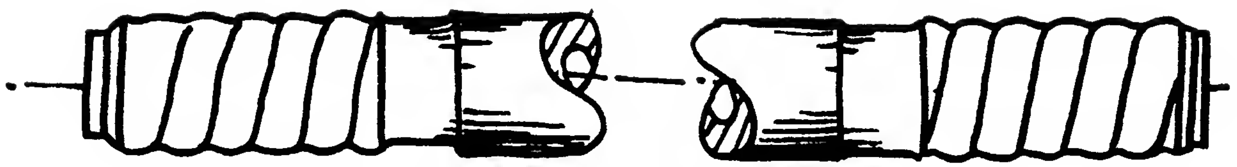


Figure 2a Reconditionable Rod

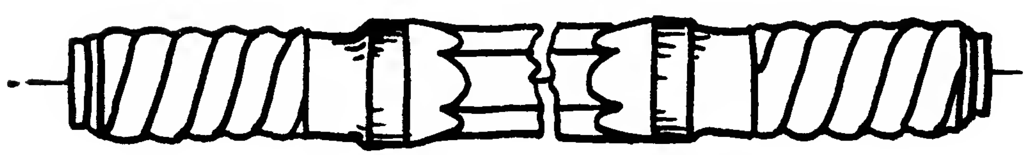


Figure 2b Carburized Rod

DEVELOPMENT EXPENDITURE REQUISITION

PLANT Phillipsburg, N. J. DIVISION Engineering REQ. NO. DER-726

D_RTMENT Rock Drill PROJECT ENGINEER E. H. Kurt DATE 4/26/63

SUBJECT: TUNNEL DRIFTER ROD SYSTEM

DESCRIPTION AND REASON FOR EXPENDITURE:

1

Cost of engineering, material and labor to design, build and test two rod and bit systems for use with the D475 Tunnel Drifter currently under development on DER-679.

Field experience on the Brooke Tunnel Job in Norway has confirmed the need for a lower operating cost rod and bit system in order for the boom and heavy drifter method of tunneling to successfully compete against the Jackdrill method. The acceptance of the D475 Drifter in this application will depend to a large degree on the development of an acceptable accessory system.

ESTIMATED COST:

Engineering:	$1,900.
Material:	13,620.
Labor:	5,110.
Test:	5,280.

TOTAL ESTIMATED COST: $25,910.00

DEVELOPMENT TIME REQUIRED & BASIS FOR TIMING:

A prototype rod and bit system will be available 12 weeks after date of approval.

PREVIOUS EXPENDITURES:

None

ATTACHMENTS: (Check or Mark Not Applicable)

SPECIAL FEATURES ____

PRODUCTION COST EST. ____

MARKET ANALYSIS & PROFITABILITY ____

SALES FORCE REQUIREMENTS ____

FOR ACCOUNTING DEPARTMENT USE

_LOPMENT ORDER NUMBER ____

DATE COMPLETED ____

AMOUNT EXPENDED ____

ACCOUNTS CHARGED ____

REPORT SUBMITTED ____

RECOMMENDED:	APPROVED:	APPROVED:	APPROVED:	APPROVED:
XXX	XXX	XXX	XXX	XXX
ENGR. IN CHARGE	PLT. CHF. ENGR. or AGM	DIVISION MGR. or PLANT MGR.	N. Y. PROD. MGR.	GEN. MGR. SALES
APPROVED:	APPROVED:	APPROVED:	APPROVED:	APPROVED:
V. P. - CHF. ENGR.	VICE-PRES.	EXEC. VICE-PRES.	PRESIDENT	CHAIRMAN

Aug. 11, 1964 J. D. DITSON **3,144,365**

METHOD OF HEAT TREATING ELONGATED STEEL ARTICLES

Filed July 10, 1963 2 Sheets-Sheet 1

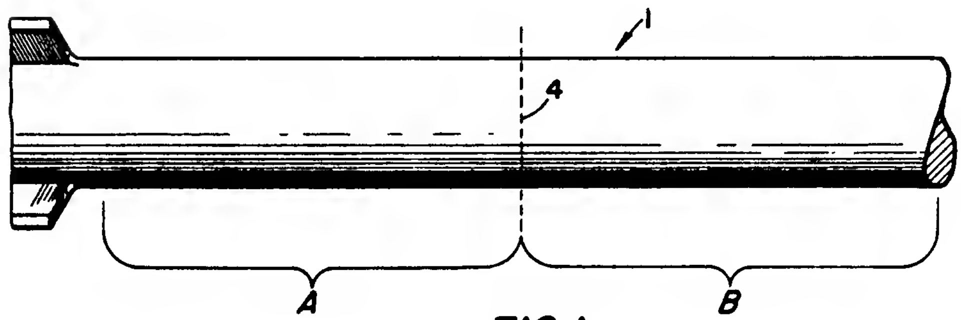


FIG. 1

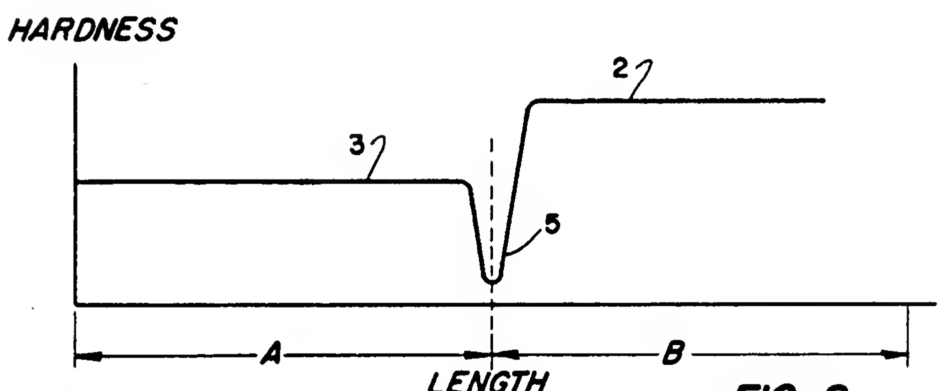


FIG. 2

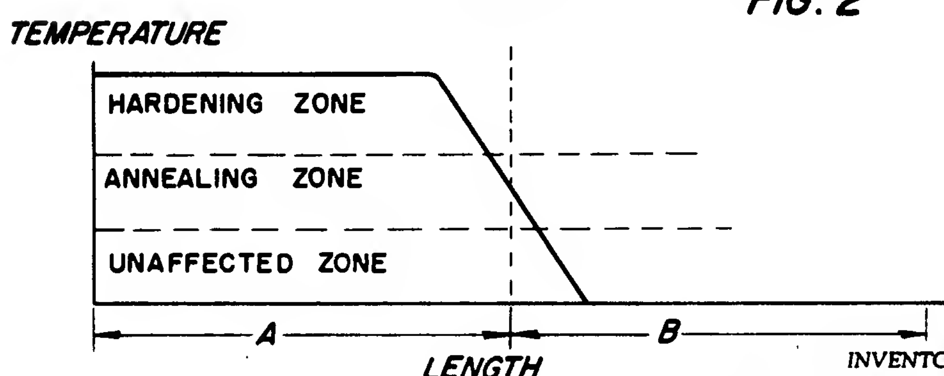


FIG. 3

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METHOD OF HEAT TREATING ELONGATED STEEL ARTICLES

Filed July 10, 1963 2 Sheets-Sheet 2

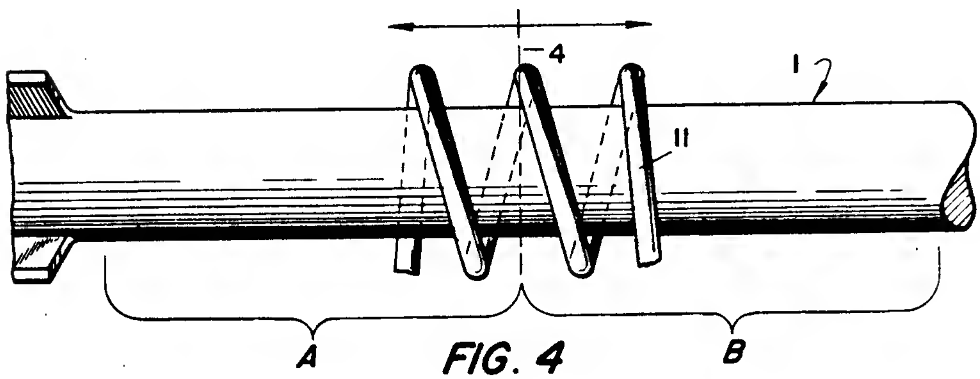

FIG. 4

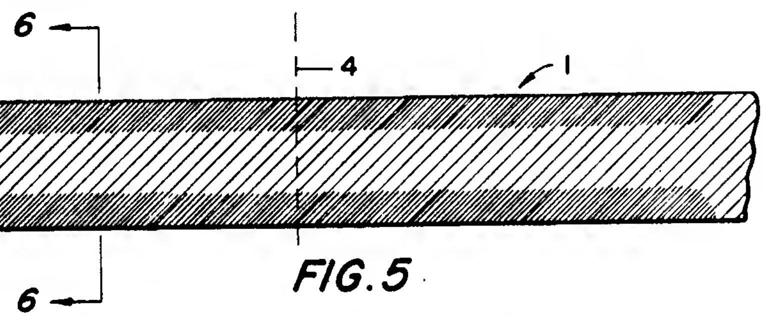

FIG. 5

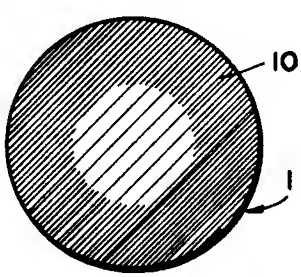

FIG. 6

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United States Patent Office

3,144,365
Patented Aug. 11, 1964

3,144,365

METHOD OF HEAT TREATING ELONGATED STEEL ARTICLES

J. D. Ditson, West Portal, N.J., assignor to Ingersoll-Rand Company, New York, N.Y., a corporation of New Jersey

Filed July 10, 1963, Ser. No. 293,986
4 Claims. (Cl. 148—145)

This invention relates to a method for heat treating elongated steel articles.

Frequently, it is necessary to heat treat a portion of an elongated steel article which has been previously heat treated. The use of this procedure may be caused by the need to give different portions of the piece different values of hardness; or, alternately, the piece may be too large for conveniently heat treating it simultaneously along its entire length. For example, the rock drill manufacturing industry often finds the need to heat treat different portions of a piece separately during the manufacture of rock drilling steels or rods.

The use of two or more heat treatments on different portions of a steel piece inherently creates a "metallurgical notch" between the two heat treated portions. A "metallurgical notch" is a soft or fully annealed zone joining the two portions of heat treated steel and is caused by the temperature gradient which inherently exists between the two portions of steel during the later heat treatment. This "metallurgical notch" zone is a weak section of the heat treated piece because it extends transversely across the entire cross-sectional area of the piece.

The principal object of this invention is to solve the "metallurgical notch" problem and to provide a method for heat treating portions of an elongated steel article separately without creating a weak "metallurgical notch" zone which makes the article more likely to break or give in the area of the "metallurgical notch."

The invention is illustrated in the drawings wherein:

FIG. 1 is an elevational view of a portion of a drill steel showing two sections which have been separately heat treated;

FIG. 2 is a curve illustrating the hardness of the drill steel of FIG. 1 at various portions of its length;

FIG. 3 is a curve illustrating the temperature gradient existing in one of the sections of drill steel during its heat treatment;

FIG. 4 is a diagrammatic elevational view illustrating an embodiment of the method of this invention;

FIG. 5 is an axial section of the drill steel of FIG. 4; and

FIG. 6 is an enlarged section taken on the line 6—6 of FIG. 5.

A steel rock drill rod 1 is shown in FIG. 1 which is subject to two separate heat treatments for hardening purposes. The drill rod 1 is divided into two sections, section A and section B. The first heat treatment provides section B with a selected value of hardness, as shown in the curve in FIG. 2 by the curve portion 2. The second heat treatment is carried out on section A to provide it with a lesser value of hardness, as shown in FIG. 2 by the curve portion 3.

During the second heat treatment of section A, an inherent temperature gradient exists between sections A and B, due to the differential temperatures of these two sections. This temperature gradient is shown in FIG. 3 by a curve having a vertical ordinate designating temperature and a horizontal ordinate designating length of the drill rod 1.

Looking at FIG. 3, the temperature of section A is in the hardening region over most of its length. However,

the portion of the drill rod 1 joining sections A and B, extending generally along the dashed line 4, has a lower temperature located in the annealing region of the steel rod. As a result, this portion or region 4 of the rod 1 will be annealed and much softer and weaker than the remainder of the drill rod 1. The annealed portion of the drill rod 1 is known in the industry as a "metallurgical notch." It obtains its name from the dip 5 in the hardness curve shown in FIG. 2.

The "metallurgical notch" is an inherent result of using a second heat treatment on the drill rod 1. It cannot be avoided. This invention recognizes this fact and does not attempt to prevent it but provides a way that the undesirable characteristics of the "metallurgical notch" can be eliminated. In other words, this invention strengthens the "metallurgical notch" so that it is no longer the weakest part of the drill rod 1.

This is carried out by subjecting the surface of the "metallurgical notch" area with a heat treatment of the type which will provide the drill rod 1 with a hardened cylindrical case 10 surrounding and extending along the "metallurgical notch" area of the drill rod. The hardened case 10 is illustrated in FIGS. 5 and 6.

The case 10 on the drill rod 1 can be formed by subjecting it to electrical induction heating currents. This can be provided by passing it relatively through an electrical induction coil 11 as shown in FIG. 4. Either the coil 11 can be moved along the drill rod 1 or the drill rod moved axially through the coil 11. The case 10 is formed by rapidly heating the surface of the drill rod 1 to hardening temperature and then cooling it rapidly so that the major portion of the rod underlying the case 10 never reaches an annealing temperature. Of course, a thin portion of the rod 1 immediately under the case 10 will be annealed but this portion is thin and parallel to the rod axis so that it does not have much effect on the strength of the rod 1.

The hardened case 10 extends over the "metallurgical notch" area and thus prevents the weak "metallurgical notch" from extending perpendicularly across the entire area of the drill rod 1. Any failure of the drill rod 1 in the "metallurgical notch" area must extend axially along the case 1 before reaching the surface of the drill rod 1. Hence, the case 10 acts to materially strengthen the drill rod 1 along the "metallurgical notch" area.

In addition, the case 10 can be formed by "flame hardening" which is carried out by applying high temperature torch flames to the surface of the rod 1 for a short time and thereafter rapidly cooling the heated surface.

Although a preferred embodiment of the invention is illustrated and described in detail, it will be understood that the invention is not limited simply to this embodiment but contemplates other embodiments and variations which utilize the concepts and teachings of this invention.

Having described my invention, I claim:

1. A method of heat treating an elongated piece of steel to provide it with two adjoining elongated sections which are hardened by separate heat treatments, said method comprising:

(*a*) heating and cooling the steel piece to harden at least a part of the steel piece including two adjoining elongated sections which are segments of the length of the steel piece;

(*b*) heating and cooling one of said elongated sections of the steel piece to harden that section of the steel piece while unavoidably creating an annealed region in the piece between the later hardened section and the earlier hardened section of the piece; and

(*c*) subjecting the surface of said annealed region to hardened case forming temperatures and rapidly

cooling the surface to create a hardened case which surrounds and strengthens said annealed region.

2. The method of claim 1 wherein said annealed region is subjected to electrical induction heating currents.

3. The method of claim 2 wherein said piece of steel is moved relatively axially through an electrical induction coil to create said hardened case in said annealed region.

4. The method of claim 1 wherein the surface of said annealed region is subjected to a high temperature flame and thereafter cooled with sufficient rapidity to prevent the major portion of the piece under the surface of the annealed region from being heated to annealing temperatures.

References Cited in the file of this patent

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2,327,129	Ronan	Aug. 17, 1943
2,845,377	Seulen et al.	July 29, 1958
2,882,191	Van Swaal	Apr. 14, 1959
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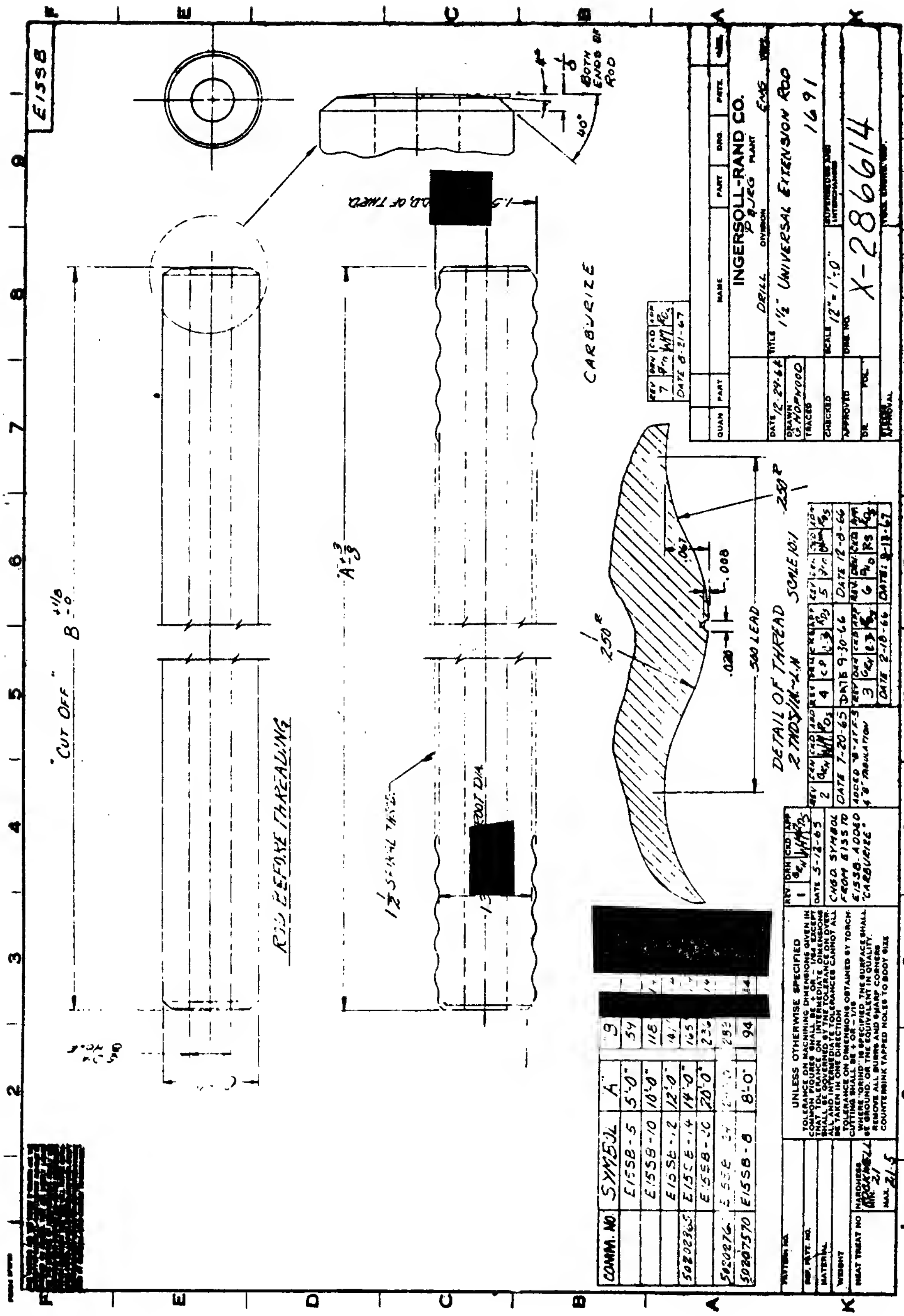
Appendix III

III-A	Drawing X-286614
III-B	Engineering Release Notice E 15SB
III-C	Material Specification 689 and 458
III-D	Drawing Y-290378
III-E	Catalog Page 4255A



Appendix III-A

X-286614

ENGINEERING RELEASE NOTICE

INGERSOLL-RAND CO. - PHILLIPSBURG PLANT

ECL 94

ROCK DRILL

* PART SYMBOL AND/OR DRAWING NUMBER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
E				1	5	S	B								2	8	6	6	1	4		2		-				
FIER	PART NO.					MACHINE DESIGNATION									DRAWING NO.						REV.		MATL. SPEC. LEFT JUSTIFIED					

PRIMARY NOUN / NOUN CODE / SUPERSEDURE CODE - CHECK ONE / PROD. CODE

30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	47	48	49
R	O	D										1	6	9	1			

LEFT JUSTIFIED — RIGHT JUSTIFIED — RIGHT JUSTIFIED

COLUMN 46: [X] (1) SUPERSEDES AND INTERCHANGEABLE [ ] (2) SUPER. AND NOT INTER

COMMUNICATION NUMBER

50	51	52	53	54	55	56	57	58
	5	0	2	0	2	3	6	5

DISPOSITION OF SUPERSEDED PART - CHECK ONE — COLUMN 59: [X] (1) USE UP IN PROCESS AND IN STOCK [ ] (2) USE FOR PART ORDERS ONLY [ ] (3) REWORK TO NEW PART. [ ] (4) SCRAP

SUPERSEDED COMM. NUMBER / MACH. CLASS-OPTIONAL / MONTH / YEAR / CARD CD. / SUPERSEDED SYMBOL (NO PUNCH) FOR RECORD ONLY

60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
																7	6	5		B

DESCRIPTION AND REASON FOR CHANGE: (NOTE ESTIMATE NO., ORDER NO., BILL OF MATERIAL, ETC., AS REQUIRED)

Added "B + 1/8 - 0 at F-5 and tabulation of "B" at B-3".

REASON: This is to give a rod dim. before machining to compensate for changes in the rod lgth. that occur during machining.

STATUS CODE - CHECK ONE - (NO PUNCH): [ ] (1) NEW-STD. [ ] (2) NEW-SPCL. [ ] (3) REVISED-STD. [ ] (4) REVISED-SPCL.

ORIGINATED BY: C.K. Meixsell

APPROVED:

TO BE COMPLETED BY ENGRG. DEPT. / TO BE COMPLETED BY MFG. DEPT.

INVENTORY CONTROL AND COST DATA

IN-PROCESS BRANCH ORDER NO'S AFFECTED:

IN-PROCESS SHOP (OR PURCHASE) ORDER NO'S AFFECTED:

STATUS OF OLD PARTS	STATUS OF NEW PARTS
STOREROOM LOCATION:	STOREROOM LOCATION:
QUANTITY ON HAND:	DATE NEW INVENTORY RECORD MADE:
QUANTITY ON ORDER:	DATE FIRST SHOP (OR PURCH) ORD. ISSUED:
USAGE LAST 12 MONTHS:	FIRST SHOP (OR PURCH.) ORDER NO:
DATE OF LAST USAGE:	DATE CASTING (FORGING) REQUEST ISSUED:
ORDER POINT:	ORDER POINT:
AMOUNT TO ORDER:	AMOUNT TO ORDER:
LEAD TIME:	LEAD TIME:
UNIT MATERIAL COST:	UNIT MATERIAL COST:
UNIT LABOR COST:	UNIT LABOR COST:
TOTAL MATERIAL COST:	DATE CASTINGS (FORGINGS) REQUIRED BY:
TOTAL LABOR COST:	DATE FINISHED PARTS REQUIRED BY:
STOCK CODE:	STOCK CODE:
ACQUISITION CODE:	ACQUISITION CODE:
COST CODE:	COST CODE:

MFG. ENGG.

NEW TOOLING OR CHANGES COMPLETED:	TIME ALLOWANCE CORRECTED:
MASTER ROUTING MADE OR CORRECTED:	SIGNED:

DISTRIBUTION OF THIS FORM:

WHITE AND BLUE COPY TO MFG. OFFICE, INVENTORY CONTROL SECTION
YELLOW COPY TO SYSTEMS DEVEL. / DATA PROCESSING DEPT.
PINK COPY TO DIVISIONAL MANUFACTURING ENGRG. DEPT.
BLUE COPY ROUTED TO DIVN. COST DEPT. THEN TO N. Y. COST DEPT.
GREEN COPY RETAINED BY ORIGINATING DEPT.

** CARD CODE DESIGNATIONS, COL. 80

A - ENGINEERING RELEASE, NO SUPERSEDING

B - ENGINEERING RELEASE, SUPERSEDING

* FOR EXPLANATION OF PART SYMBOL ZONING REFER TO REVERSE SIDE.

FORM G-2293 R2 (4-66)

Third EDITION	INGERSOLL-RAND STANDARDS
EFFECTIVE 12-7-66	MATERIAL SPECIFICATION 689
SUPERSEDES Second	TUBULAR JACKROD STEEL

1.0 SCOPE:

1.1 This specification covers seamless cold-finished alloy steel mechanical tubing for use as tubular drill rods. The purchase order shall specify the applicable drawing and part number and shall, in addition, state the quantity, outside diameter and wall dimensions, length and end condition. When upsetting is required, it shall be so stated.

2.0 MELTING REQUIREMENTS:

2.1 The steel shall be made by the Electric Furnace Process.

3.0 CHEMICAL REQUIREMENTS:

3.1	C	Mn	P	S	Si	Cr	Mo
Min.	.25	.80	-	-	.50	1.90	.25
Max.	.31	1.20	.025	.025	.80	2.40	.35

Residual Nickel must be less than .15

The chemical composition is subject to the standard variations for check analysis as set forth in the current edition of the Steel Tubular Products Section of the A.I.S.I. Steel Products Manual.

4.0 PHYSICAL REQUIREMENTS:

4.1 After cold finishing, the tubes shall be stress relieved aiming at a hardness level of BHN 229/279.

4.2 The steel shall have the capacity to harden to BHN 375 minimum when cooled in still air from an austenitizing temperature of 1600°F.

5.0 SURFACE REQUIREMENTS:

5.1 After stress relieving, the tubes shall be machine straightened and finished to the size and tolerance specified on the order.

5.2 Processing shall be such that a surface free from defects, seams and decarburization and suitable for thread rolling is provided.

5.3 The surface of the bore shall be free from rust and all seams and defects outside commercial limits, which shall be negotiated.

Third EDITION EFFECTIVE 12-7-66 SUPERSEDES Second	INGERSOLL-RAND STANDARDS MATERIAL SPECIFICATION 689 TUBULAR JACKROD STEEL

6.0 QUALITY REQUIREMENTS:

6.1 Within the limits of good manufacturing and inspection practices, the material shall not contain any defects which, due to their nature, degree or extent, prevent fulfillment of the requirements of this specification.

7.0 MECHANICAL REQUIREMENTS:

7.1 Outside diameter and tube wall tolerances shall be as specified on the purchase order.

7.2 Length tolerances shall be in accordance with the current edition of the A.I.S.I. Steel Products Manual.

8.0 INHERENT STRUCTURAL REQUIREMENTS:

8.1 The steel shall be killed, fine-grained in accordance with the current A.I.S.I. definition.

9.0 INSPECTION AND REJECTION:

9.1 Material failing to satisfy the intent and purpose of this specification will be rejected and the manufacturer will be notified. After acceptance by the manufacturer of responsibility for the rejection, the rejected material shall be returned for full credit at prices charged, including all transportation expenses.

10.0 PACKING REQUIREMENTS:

10.1 The supplier shall remove any residual grit from the bore of the tubes and package to prevent damage in transit.

10.2 The supplier shall furnish our Purchasing Department with a notice of shipment, showing the order number, weight and number of tubes.

10.3 A representative test specimen, consisting of a 2 foot length of finished tube from each heat, shall be furnished to the Phillipsburg Materials Laboratory along with a test report, indicating heat number analysis and hardness.

Seventh Edition Effective June 20, 1961 Supersedes 6th Edition	INGERSOLL-RAND STANDARDS MATERIAL SPECIFICATION 458 .25% C-MN-SI-NI-MO ALLOY STEEL

1. SCOPE:
This specification covers a low alloy ("ULTRA STRENGTH") through hardening steel. This material possesses relatively high impact strength and good ductility when used at 220,000/240,000 psi ultimate strength level. It may be purchased either unannealed for reforging or annealed for optimum machinability.

2. MELTING REQUIREMENTS:
Electric furnace.

3. CHEMICAL REQUIREMENTS (U.S. Patent #2,447,089):

	C	Mn	P	S	Si	Ni	Cr	Mo
Min.	.23	1.20			1.30	1.65		.35
Max.	.28	1.50	.025	.025	1.70	2.00	.40	.45

AISI Standard check analysis tolerances will apply.

4. PHYSICAL REQUIREMENTS:
(a) Material under 6" intended for forging shall be ordered annealed to make it suitable for cold sawing.
(b) Material ordered for machining shall be annealed for optimum machinability and shall have a maximum Brinell hardness of 241 (Rockwell "C" 23).
(c) End quench hardenability tests shall be made according to ASTM-A255, the hardenability index shall be Rockwell C-47 minimum at 8/16 inch and C-45 minimum at 24/16 inch after being normalized at 1700°F for one hour, cooled in still air and austenitized at 1575°F.

5. SURFACE REQUIREMENTS:
(a) Forging Billets:
Hot-rolled or smooth forged.
(b) Bars:
1. Hot-rolled or smooth forged.
2. Bars up to and including 4 1/2" ordered annealed for machining, shall be pickled and free from scale.

6. QUALITY REQUIREMENTS:
Within the limits of good manufacturing and inspection practices, the material shall not contain any defects which, due to their nature, degree or extent, prevent fulfillment of the requirements of this specification.

7. MECHANICAL REQUIREMENTS :
(a) Billets:
According to the latest AISI Standard Practices.
(b) Bars:
1. AISI standard tolerances for hot rolled bars will apply.
   (a) Tolerances for forged or forged and rough turned bars shall be negotiated.
2. Hot rolled bars ordered for forging shall be commercially straight.
   (a) Tolerances for straightness of forged bars shall be negotiated.
3. Bars ordered annealed for machining shall be machine straightened. Bars over 4 1/2" shall be commercially straight.
4. Random lengths shall be supplied unless otherwise specified on the purchase order.
5. Bars ordered cut to length shall conform to limits of the latest AISI steel products manual, AISI "Hot-rolled Alloy Steel".
6. Forged Bars 8-5/8" round and over are to be rough turned to a diameter tolerance of plus 1/8", minus .000"

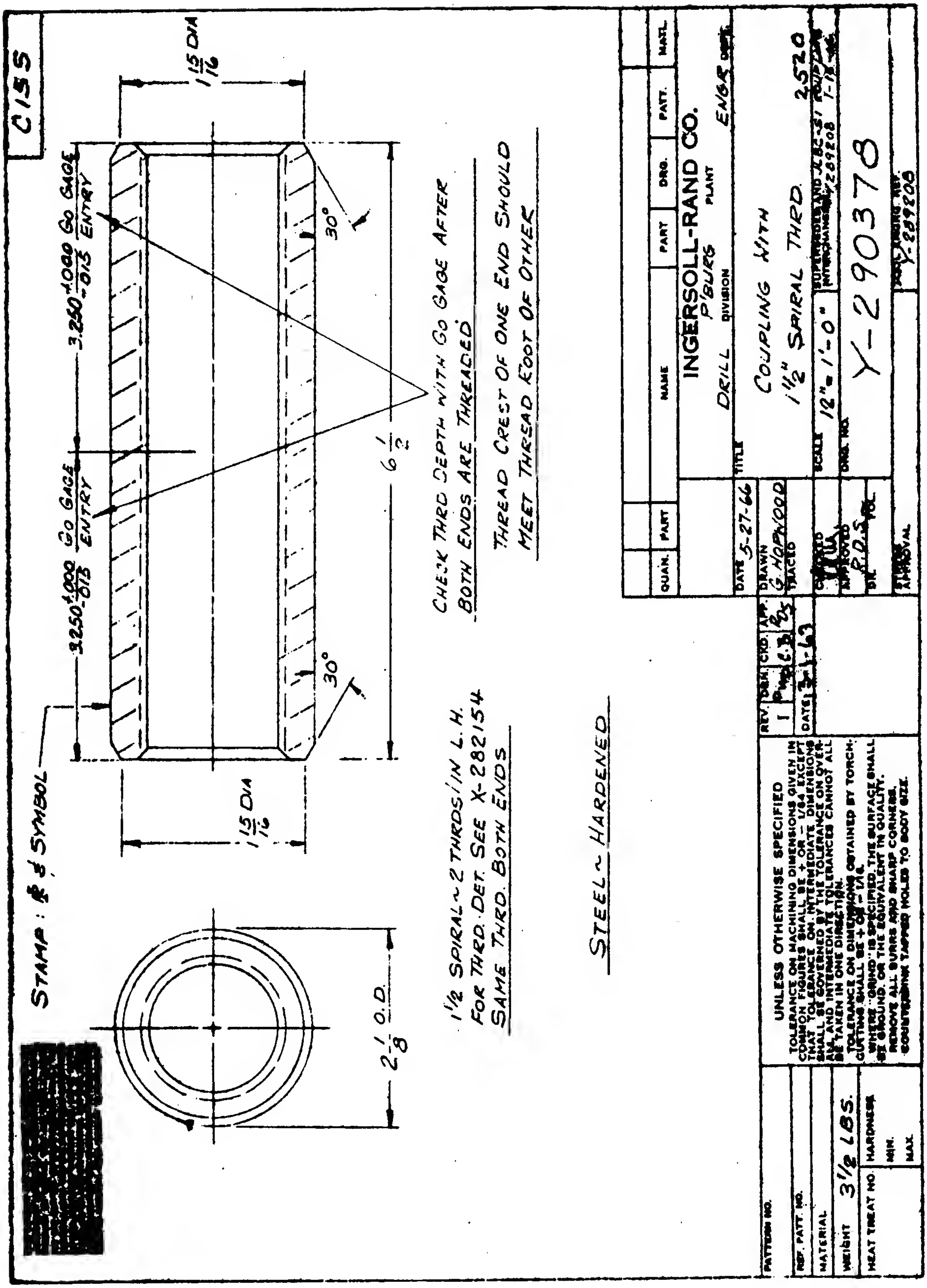
8. INHERENT STRUCTURAL REQUIREMENTS:
The steel shall be killed, fine-grained in accordance with current AISI definition.

9. INSPECTION AND REJECTION :
Material failing to satisfy the intent and purpose of this specification will be rejected, and the manufacturer will be notified. After acceptance by the manufacturer of responsibility for the rejection, the rejected material shall be returned for full credit at prices charged including all transportation expenses.

10. PACKING REQUIREMENTS:
(a) All bars and billets shall have the heat number stamped on one end in accordance with the manufacturer's practice for which no extra charge is involved. Bars that entail an extra shall not be stamped, but shall be bundled and tagged for identification.
(b) The manufacturer must furnish our Purchasing Department with a notice of each shipment showing the chemical analysis, the order number and weight of bars.

This specification was issued September 29, 1960, to provide for the purchase of the Crucible Steel Company brand known as HY-TUF (similar composition but aircraft quality) in regular electric furnace alloy steel quality. Licensees are Timken Steel Co., Rotary Steel Division of Jones and Laughlin Co., and Carpenter Steel Co.

Usage of this specification is discussed in Material Engineering Practices Book Page 29.02.


C155
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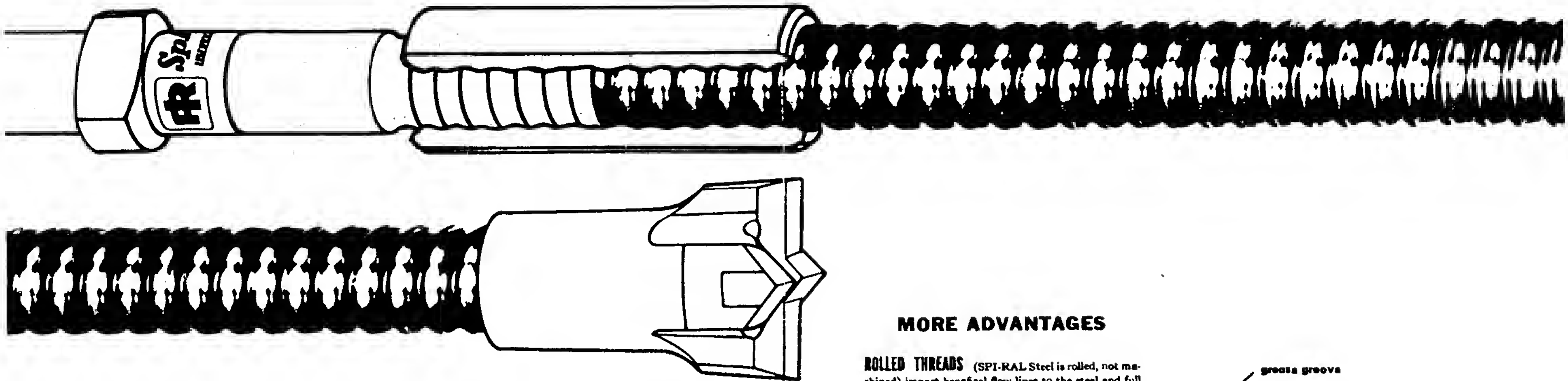
3.250 +.000 -.013 GO GAGE ENTRY
3.250 +.000 -.013 GO GAGE ENTRY
1 15/16 DIA
1 15/16 DIA
30°
30°
6 1/2
2 1/8 O.D.
CHECK THRD DEPTH WITH GO GAGE AFTER BOTH ENDS ARE THREADED
THREAD CREST OF ONE END SHOULD MEET THREAD ROOT OF OTHER
1 1/2 SPIRAL ~ 2 THRDS/IN L.H.
FOR THRD. DET. SEE X-282154
SAME THRD. BOTH ENDS
STEEL ~ HARDENED
INGERSOLL-RAND CO.
P'BURG PLANT
DRILL DIVISION
ENGR DEPT.
COUPLING WITH
1 1/2" SPIRAL THRD.
2520
SCALE 12" = 1'-0"
DATE 5-27-66
DRAWN G. HOPWOOD
APPROVED R.D.S.
DWG. NO. Y-290378
Y-289208
UNLESS OTHERWISE SPECIFIED
WEIGHT 3 1/2 LBS.
PATTERN NO.
REF. PATT. NO.
MATERIAL
HEAT TREAT NO.
HARDNESS
MIN.
MAX.

- **The first drill steel that is fully threaded.**
- **If a rod breaks, just cut off the broken end.**
- **No rethreading, no heat treating.**

BLUE RIBBON EQUIPMENT AWARD
To INGERSOLL-RAND SPI-RAL-STEEL
for technological achievement in equipment development for the world minerals industry
WORLD MINING



The greatest advance in drill steel since the hollow rod.

Ingersoll-Rand's SPI-RAL-Steel represents an entirely new concept in reconditionable drill steel—a concept that can save you countless hours of time and drastically cut cost per foot of hole.

Because the rod is threaded throughout its entire length, no rethreading is ever needed. This does away with costly rod shop equipment—threading machines and heat treating furnaces.

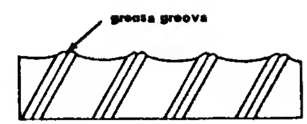
The entire "rod shop" now consists of a simple, air driven cutoff machine that you can mount right on the drill. When a steel breaks, all you do is clamp it in the cutoff machine and pull down the handle to square off the end. No steel is wasted in reconditioning. Chamfer the rough edges and its ready to screw back in place and go to work. That's all there is to it.

In addition to all the time and money saved on reconditioning, you'll find that you can operate on a much smaller inventory of steel—because none of it is tied up in the rod shop.

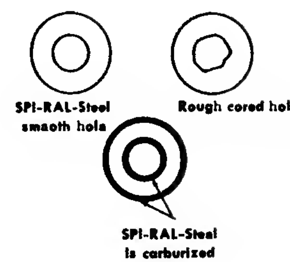
Ingersoll-Rand SPI-RAL-Steel is now available in 1½" (38 mm) diameter, 10' (3 m) and 12' (3.6 m) lengths—E15SB-10 and E15SB-12. Matching shank pieces, couplings and Carset bits are also available.

MORE ADVANTAGES

ROLLED THREADS (SPI-RAL Steel is rolled, not machined) impart benefical flow lines to the steel and full length threads have the added advantage of tending to lift mud collars to the surface with normal rotation. The small groove at the crest of the thread retains grease and assures faster, easier uncoupling. The uniform section of Ingersoll-Rand SPI-RAL rods eliminates undercuts and sharp corners that are stress raisers.



MORE UNIFORM CENTER HOLE. Made from finest quality steel tubing, SPI-RAL-Steel has a uniform diameter, smooth-surface center hole. Compared to steel with imperfect, off-center cored holes, it is stronger and offers less air resistance.



CARBURIZED INSIDE AND OUT, SPI-RAL-Steel has the right combination of hardness to withstand surface wear, and toughness to resist breaking.

35% to 50% LOWER COST PER FOOT OF HOLE. Based on average reconditioning costs it is conservatively estimated that SPI-RAL-Steel can cut overall steel cost by 35% to 50% or even more.

Instructor's Notes

This case was used at Stanford in the undergraduate course on Manufacturing Methods and Materials to show the close relation between design, product performance, materials, manufacturing methods, and capital equipment. At the same time it was used to show examples of shop drawings with revision, revision Release Notice, Materials Specifications, a patent, and a Development Expenditure Requisition. It was felt that acquaintance with such papers, even without detailed discussion, was worth the time spent on reading them carefully.

Several exercises can be based on this case, such as:

1) Explain how the coupling (Appendix III - D) can be manufactured. Note that "Thread crest of one end should meet thread root of the other." (The couplings are threaded, one end at a time, on an Italian machine which cuts the thread with a tool like a boring bar from one end to the middle, then retracts radially, moves out of the bore, gets radial feed, proceeds to take another cut, and repeats until half of the coupling thread is formed. The process is repeated for the other end. Exact axial and angular positioning of the coupling in the machine are essential.) Students may propose other methods. The job could be done on an ordinary lathe.

2) Explain how the correct relative position of the two threaded ends of the coupling can be inspected. (By observation of the relative angular positions of the thread roots at the ends of the couplings.)

3) Explain item 6 of Materials Specification 689. (It covers contingencies which the specifier could not foresee in detail.)

4) Set up the calculations (with estimated numbers) by which John Adams justified the expenditure of $75,000.

5) Document the advantages of carburized rods by reference to published data on the stresses produced by carburizing. (See, for instance, Almen and Black, Residual Stresses and Fatigue in Metals, page 202.)

6) Estimate the magnitude of self-stresses produced in carburizing from the specific volumes of martensite and pearlite. (High carbon steel expands about 1% in volume when transforming to martensite; the stress would then be about 0.003 E = 100 ksi in each direction in which expansion is prevented.)

7) Explain the difference in length of the rods before and after thread-rolling. (The radial squeeze of the rolls is large enough, with these broad threads, to force the rod material to flow lengthwise.)

8) Note that thread tolerances have been censored out of the rod drawing (appendix III - A) and are not given on the coupling (appendix III - D). Make sketches of the male and female threads with suitable tolerances.

9) Sketch gages by which threads can be checked for conformity with the tolerances you have specified.

10) Specify tolerances for the gages.

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